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(72) HATAMI-HANZA, HAMID, CA
(71) HATAMI-HANZA, HAMID, CA

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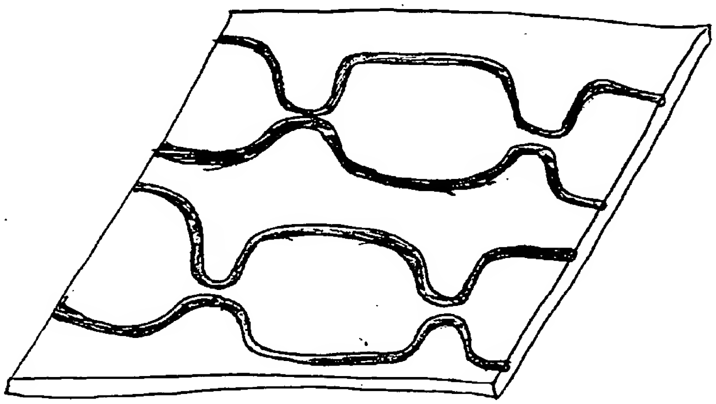
(54) **PROCEDE POUR MESURER LE VOLUME DES DISPOSITIFS A FIBRES OPTIQUES A GAMME D'ACCORD ETENDUE**

(54) **METHOD FOR VOLUME PRODUCTION OF OPTICAL GRATING DEVICES WITH TUNING CAPABILITY**



(57) The present invention provides a method of fabricating grating on the designated areas of optical waveguide devices that contain photo-refractive material in at least one of the core and cladding regions. The said optical waveguides are fabricated or embedded on a sample substrate by one of the associated suitable methods. Using the first mask, having openings corresponding to areas allocated for writing gratings on the waveguide circuit, and conventional lithography, the said waveguide circuit is covered by a masking material, such as chromium or any other suitable material, exempt those areas allocated for writing gratings by the exposure to a particular electromagnetic radiation spectrum for which the waveguide is photo-refractive in at least one of the core or cladding areas. Alignment markers are also transferred onto the sample at this stage. Then we fabricate the phase mask, which is a copy of the said first mask except that it is containing the phase gratings on the open areas of the first mask. Then we place strips of a soft gasket with a desired thickness on the side edges of the patterned sample and then place and attach the said phase mask over the sample by means of clips or the like so as to allow a desired distance between the phase mask and the sample. Using a mask aligner and by aligning the markers on the sample and the phase mask we make sure the phase gratings are exactly placed on the designated areas for writing gratings. The sample with the phase mask attached over it is then exposed to the said particular electromagnetic radiation for a certain time to create a grating on the designated areas. After imprinting the grating on the designated areas the said phase mask is removed for later use. Final adjustment of the grating device is done at the latest stage of manufacturing or by the consumer by further exposure to an attenuated electromagnetic radiation to tune the average refractive index alteration on the desired areas and achieve the desired wavelength response from the waveguide circuit by monitoring the wavelength response. Since in this method the phase mask is attached to the sample, writing grating can be done under less constrained conditions in terms of vibration and the quality of electromagnetic radiation used for imprinting the grating. Several gratings can be fabricated over the waveguide circuit at the same time without a need for precise mechanical motions. Long fiber grating also can be fabricated by the same principle by embedding fibers in a planar base.

Method For Volume Production Of Optical Grating Devices With Tuning Capability

INVENTOR: Hamid Hatami-Hanza
APPLICANT: #1401-475 Elgin Street,
Ottawa, Ontario, K2P 2E6 Canada

Abstract

The present invention provides a method of fabricating grating on the designated areas of optical waveguide devices that contain photo-refractive material in at least one of the core and cladding regions. The said optical waveguides are fabricated or embedded on a sample substrate by one of the associated suitable methods. Using the first mask, having openings corresponding to areas allocated for writing gratings on the waveguide circuit, and conventional lithography, the said waveguide circuit is covered by a masking material , such as chromium or any other suitable material, exempt those areas allocated for writing gratings by the exposure to a particular electromagnetic radiation spectrum for which the waveguide is photo-refractive in at least one of the core or cladding areas. Alignment markers are also transferred onto the sample at this stage. Then we fabricate the phase mask, which is a copy of the said first mask except that it is containing the phase gratings on the open areas of the first mask. Then we place strips of a soft gasket with a desired thickness on the side edges of the patterned sample and then place and attach the said phase mask over the sample by means of clips or the like so as to allow a desired distance between the phase mask and the sample. Using a mask aligner and by aligning the markers on the sample and the phase mask we make sure the phase gratings are exactly placed on the designated areas for writing gratings. The sample with the phase mask attached over it is then exposed to the said particular electromagnetic radiation for a certain time to create a grating on the designated areas. After imprinting the grating on the designated areas the said phase mask is removed for later use. Final adjustment of the grating device is done at the latest stage of manufacturing or by the consumer by further exposure to an attenuated electromagnetic radiation to tune the average refractive index alteration on the desired areas and achieve the desired wavelength response from the waveguide circuit by monitoring the wavelength response. Since in this method the phase mask is attached to the sample, writing grating can be done under less constrained conditions in terms of vibration and the quality of electromagnetic radiation used for imprinting the grating. Several gratings can be fabricated over the waveguide circuit at the same time without a need for precise mechanical motions. Long fiber grating also can be fabricated by the same principle by embedding fibers in a planar base.

Method For Volume Production Of Optical Grating Devices With Tuning Capability

INVENTOR: Hamid Hatami-Hanza
APPLICANT: #1401-475 Elgin Street,
Ottawa, Ontario, K2P 2E6 Canada

Field of Invention

This invention generally relates to optical waveguide circuit and devices and more particularly to those devices containing waveguides with grating structures.

Background of the Invention

Optical Bragg grating devices are used for performing many operations on optical signals, such as filtering, light diffraction, and sensing. Optical waveguide grating, in particular, do theses function while guiding and confining the light in the waveguide medium as well. A waveguide grating is normally formed on a waveguide in which at least one of its parameters is changed almost periodically along the length of the waveguide. The most commonly perturbed physical parameter in waveguide grating structures is the refractive index. The waveguide structure with periodically perturbed refractive index can be used as an optical filter in which an optical signal is reflected back by the grating structure at the Bragg wavelength defined by:

$$\lambda_B=2n_{eff}\Lambda$$

where λ_B is the Bragg resonance wavelength and n_{eff} is the average effective index of the waveguide, and Λ is the longitudinal period of refractive index change along the waveguide. A variety of optical wavelength band reflection/rejection or transmission filters can be designed consequently to perform the desired functions. The optical filter can be designed to have very narrow, i.e. less than 0.1 nm line-width, or to have relatively wide band filters with desired transmission reflection wavelength characteristics in the order of few tens of nm line-width. For instance they can be used for separating one particular band of the optical signal in wavelength division

multiplexing (WDM) optical transmission system or as dispersion compensators in long haul transmission systems.

An efficient and popular method of imprinting gratings on waveguides is to use photosensitive waveguides whose refractive index can be changed once exposed to a particular spectrum of electromagnetic radiation. Usually grating is imprinted by exposing the waveguide under a interferometric pattern of ultraviolet (UV) sources using holographic or phase mask methods. Imprinting grating by holographic method has been described, for instance in an article by G. Melts et al. published in Optics letter Vol. 14, No. 15, page 823-825, 1989, entitled, "Formation of Bragg gratings in optical fiber by transverse holographic method," the disclosure of which is incorporated herein as a reference. In the holographic, or interferometric method, waveguide grating is formed by exposing the piece of fiber to an interfering pattern of two ultraviolet (UV) beams of light to produce a standing wave to which the waveguide is exposed. The refractive index of the waveguide is locally and periodically changed in the exposed area. This grating fabrication approach requires a laser with high spatial and temporal coherence, and is highly sensitive to alignment and vibration during production. These requirements are more strict in the case of chirped grating in which the period of grating pitches must be changed along the waveguide.

Imprinting grating using a phase mask method, has been described, for instance, in an article published in Applied Physics Letters, Volume. 62, Number 10, page 1035-1037, 1993, entitled, "Bragg Gratings Fabricated In Monomode Photosensitive Optical Fiber By UV Exposure Through A Phase Mask," by K.O. Hill et al.; and also in the US patent 536,7588, issued Nov. 22, 1994 entitled, "Method of fabricating Bragg grating using a silica phase grating mask and mask used by same," also by K. Hill et al, the disclosure of which are incorporated herein as references. In this approach, a phase mask splits the beam into several diffractive orders that interfere to create the required pattern. The phase mask method is less sensitive to spatial coherence and alignment. It can also be used to produce chirped gratings. However it still needs proper optical alignment, careful control of the space between the phase mask and the waveguide, with a precise control of

waveguide motion under phase mask at the same time. In the US patent No. 83,7169, " Creation of Bragg reflective gratings in waveguides," by H. N. Rourke, Issued Nov. 1998, there is disclosed a method of writing long fiber grating at several stages using a number of phase masks that have an alignment part which is a replicate of the portion of the writing part of the adjacent mask. Careful motion adjustment must be made to align the consequent masks and keep the writing conditions the same for each stage of writing gratings.

A number of research papers and patent disclosures, some of which have been listed hereinbelow, are found in the literature proposing new optical devices using Bragg grating or disclosing improved methods of imprinting Bragg grating based on the two above mentioned methods. Nevertheless, grating fabrication method using these approaches are still time consuming and unpredictable due to the required mechanical motion accuracy and stability. This results in low yield in fabrication and therefore a high manufacturing cost. Therefore there is a need in the art for alternative methods of manufacturing Brag grating devices on waveguides that is suitable for volume manufacturing.

Summary and objectives of the invention

The present invention provide a method of fabricating waveguides or fiber gratings suitable for mass production with post tuning capabilities. In this method a waveguide circuit is fabricated by one of the conventional methods of fabricating planar waveguides such as flame hydrolysis, sol-gel deposition and the like or by embedding optical fiber in a planar base. At least one area of the waveguide in which a guiding mode is wholly or partially propagated contains photo-refractive materials. A photo-refractive material is a material whose refractive index can be altered by an exposure to a particular spectrum of an electromagnetic radiation. To write a grating in the designated areas, the said waveguide circuit is covered by a masking layer of a metal or any other material that is not transparent to the said particular spectrum of electromagnetic radiation. A first mask is provided that has openings corresponding to the those designated areas that we wish to create gratings on the waveguide circuit. Through lithography we transfer the said

openings of the said first mask onto the said designated areas of the said waveguide circuit that is covered by the said layer of masking . Alignment marks are also transferred from the first mask onto the waveguide circuit surface.

Then we fabricate a phase mask copy which is identical to the first mask except that phase grating have been fabricated on the said openings corresponding to the designated areas of waveguide circuit for which we wish to create a grating by exposure to a electromagnetic radiation. The phase mask can be fabricated by electron beam lithography and the associated etching methods over a silica substrate. The said phase mask also has alignment marks for matching the said phase grating on the opening pattern of the waveguide circuit surface covered with the said masking layer.

Then strips of a soft gasket is placed on the edge corners of the waveguide circuit and the said phase mask is brought into close proximity to the surface of waveguide circuit and placed over the gasket in a situation that the markers on the waveguide circuit surface and that of the phase mask are in alignment. The said phase mask is then pressed over the gaskets and affixed on the waveguide circuit temporally by means of clips or adhesives or the like so that the mask is attached to the waveguide circuit in a proximity distance of the gasket's thickness. The thickness of the gaskets can be selected in the range of 10 to 100 micron.

The waveguide circuit with the said phase mask attached to it is then exposed through the phase mask to the said electromagnetic radiation to make a permanent refractive index change in the core or cladding or both areas of the waveguide sensitive to that particular spectrum of the said electromagnetic radiation.

Since the phase mask is intact to the waveguide circuit, grating can be fabricated by exposing to a non-coherent light source such as a UV lamp and vibration free condition become less critical. Chirped grating also can be produced by chirping the period of the phase mask at the electron beam lithography stage. After a certain amount of exposure time gratings are formed in the designated areas of the waveguide circuit and then the phase mask is removed. The said masking layer may or may not be removed or the opening pattern might be changed by another stage of lithography. Once the phase mask

is removed the wavelength response of the grating device can be adjusted by locally exposing the written grating or certain areas of the waveguides to an attenuated radiation to change the average refractive index, thereby adjusting or shaping the wavelength spectrum response of the waveguide circuit with grating. Since this process is repeatable and does not need careful mechanical condition monitoring or highly spatial coherent radiation sources, and therefore is more predicable, it is more suitable for a volume production line.

In summary, it is an object of the present invention to provide a method in which many gratings can be written accurately and with less critical conditions in a large volume manufacturing process.

It is another object of the present invention to provide a method for post tuning of the grating devices thereby the possibility of shaping their wavelength responses.

Brief description of the drawings

Fig. 1: shows a sample substrate with a waveguide circuit fabricated thereon. The waveguides are photo-refractive in at least one of the core or cladding regions.

Fig. 2a and 2b show embodiments of samples in which fibers have been embedded in the substrate in the form of parallel pieces of fibers and a long piece of fiber in form of a spiral.

Fig 3. Shows the sample, with waveguide circuit fabricated therein, is covered with a masking layer with opening in the areas designated for creating grating on waveguides and with alignment marks.

fig 4 shows the phase mask copy with a pattern of gratings written on the designated areas by electron beam lithography and with alignment marks.

Fig. 5. shows that gaskets are placed on the edge corners of the waveguide circuit and the phase mask is being placed closely over the waveguide circuit, while marks on both waveguide circuit surface and the phase mask are in complete alignment.

Fig. 6 demonstrates writing grating on the waveguide circuit with the phase mask attached to it, by ultraviolet light exposure.

Fig 7. shows an optical circuit for post tuning of the grating after removing the phase mask using an attenuated ultra violet source.

Detailed description

Fig 1. shows one embodiment of an exemplary integrated optic circuit for which we want to write a grating in the designated areas. The waveguide circuit contains a photosensitive material in at least one of the core or cladding area. The photosensitive materials are often photo-refractive to a particular spectrum of an electromagnetic radiation. In here we emphasize on the photosensitive materials that their refractive index is changed noticeably upon an exposure to an ultraviolet (UV) light. Other materials showing photosensitivity to other spectrums of the electromagnetic radiation may also be used. Waveguides containing at least one photosensitive area can be fabricated for instance by depositing a layer of photosensitive sol-gel glass as the cladding on the waveguide circuits, made of variety of materials, as disclosed in a Canadian patent pending no. 2190-886 by H. Hatami-Hanza et al. filed Nov. 21, 1996. The waveguide circuit can also be made entirely by sol-gel glass method as described for instance in an article, "Fabrication and Characterization of Low-Loss, Sol-Gel Planar Waveguides, Anal. Chem, pp. 1254-1263, Vol. 66, 1994; and in another article, "Ultraviolet light imprinted sol-gel silica glass channel waveguides on silicon, Authored by Najafi et al, published in SPIE, 38-41, vol. 2695, 1996, the disclosure of which are incorporated herein as references. Waveguide with at least one photosensitive area can also be fabricated by flame hydrolysis method using germanium doped silica glass deposition as described in an article by Jorg Huber et al. entitled, "UV-Written Y-Splitter in Ge Doped Silica," published in SPIE vol. 2695, PP. 98-105, 1996 disclosure of which is incorporated herein as a reference.

In another embodiment of samples, as shown in Fig 2a and 2b, fibers have been embedded in a substrate such as glass or a silicon. The method of embedding fibers in a substrate has been described in another disclosure by H. Hatami Hanza and V. Benham,

filed in Canada, entitled, "An Integrated Optical Board Comprising Integrated Optic Waveguide Circuit Modules". In this particular embodiment fibers are first embedded in the substrate in grooves with the desired shape. The embedded fibers are then affixed and perhaps covered by an adhesive and annealed to solidify the substrate with the fibers embedded therein. The said substrate with embedded fiber therein is then polished to achieve almost optically flat surface wherein the cladding or core of the fibers imbedded therein is exposed to air. In Fig 2a pieces of fibers have been embedded in parallel grooves on a substrate and Fig 2b shows that a long piece of fiber has been embedded in form of a spiral in a substrate. These embodiments are particularly useful for writing long grating on the optical fiber for applications such as dispersion compensation.

Having a sample, with the waveguide circuit or embedded fiber therein as shown in Fig 1m 2a, and 2b, now we wish to write gratings on designated areas of the sample. Each sample may be few millimeter to few inches, 6-8 inches, wide in one or both side. Fig. 3 shows that the sample is first deposited by a thin layer of a material which is not transparent to UV light. The deposited layer can be a metal, such as chromium or aluminum, or any other suitable material which is not transparent to UV, such as polymer resists and the like. Next a pattern is transferred from a mask, herein referenced as the first mask, and defined on the said layer by conventional photolithography or by electron-beam lithography. The pattern has openings over the areas that are allocated for writing grating as well as having alignment marks. The fundamentals of the lithography and the associated process are described for example in a monograph entitled "Eximer Laser Photography," by Kanti Jain, published in SPIE, 1989 or in a book entitled "Introduction to Microelectronics Fabrication, Molecular Series on Solid State Devices," Authored by Richard Jaeger, editors; Gerold W. Neubeck, Robert F. Pierret, Addison-Wesley Publishing Company, vol. 5, 1993, the disclosure of which are incorporated herein as references.

The next step is to fabricated a phase mask copy of the said first mask which is identical to the said first mask except it also has phase grating, with the desired pitches and shapes, on the openings corresponding to the areas allocated for writing grating as shown in Fig

4. The phase mask can have as many phase gratings as one can fabricate over the said mask with the given areas and moreover it may include phase gratings with chirped pitches with the desired lengths. A phase mask can be fabricated over a silica substrate by direct electron-beam writing over a silica substrate, masked with a layer of resist or metal, followed by an associated etching method to create an etched phase grating over the silica for the desired wavelengths. The fundamentals of electron beam lithography and the associated processes are described, for instance, in the book entitled: "Electron-based Technology in Microelectronics Fabrication," Edited by Goarge Barnere Published by Academic Press, chapter 5, 1980, the disclosure of which is incorporated herein as a reference.

Referring to Fig 5 now, it shows the assembly for writing grating on the designated areas. Strips of a soft gaskets such as Teflon or the like is placed on the corner edges of the sample; then the phase mask is brought into close proximity with the sample and placed over the gaskets in such a way that markers of both phase mask and the sample surface are in precise alignment ensuring the satisfactory matching of the phase grating on the corresponding opening on the sample surface. The phase mask is than pressed and attached to the sample by means of clips or perhaps with temporary adhesive or the like. The thickness of the gaskets may be selected between 10 to 100 micron depending on the flatness of the sample surface. The placement of gaskets ensures that the phase mask is affixed on the surface of the sample at the certain distance from the sample and the sample and the phase mask do not move relative to each other once attached to each other.

Referring to Fig 6 now, it shows the sample with attached phase mask under a UV exposure. Since the phase mask is attached to the sample, the vibration free condition over the time for writing grating on the photosensitive waveguide is greatly relaxed and the exposure can be done in a clean environment with a broad band UV source such as UV lamps. The source of the electromagnetic radiation can be a UV lamp with large aperture area, so that the radiation covers the whole area of the waveguide circuit or the planar base with the embedded fiber therein.

After exposing the sample to the UV light for the certain amount of time the phase mask is detached and is kept for the next exposure. After writing gratings in the designated areas by the method described above, the masking pattern over the sample may be removed or it may undergo one or more additional level of lithography before packaging.

Referring to Fig 7 now, it shows an optical set-up that can be used for the final adjustment of the grating by locally exposing the waveguide to an attenuated radiation while monitoring the wavelength responses of the device to achieve a desired response from the waveguide circuit. The setup includes a signal source coupled to the waveguide circuit wherein the waveguide circuit is positioned over a computer controlled X-Y motion table and a limited spot size UV beam is directed over the designated areas. The limited spot size UV beam is coming from a UV source which passes through a variable attenuator to have the desired intensity. This final step of adjustment can be performed before or after the packaging or by the consumer.

The above described process is repeatable and sequential with almost predicable results and does not need careful mechanical condition monitoring or highly spatially coherent radiation sources. It is therefore more suitable for a volume production line to lower the cost of optical waveguide devices with photo-imprinted grating structures. Those expert in the art appreciate that the above particular descriptions illustrate only the principles of the present invention. It will be understood that various modifications could be made by those skilled in the art without departing from the scope and spirit of the present invention, which is limited only by the following claims.

References

US Patents

Patent No.	*Date of Issue*	*Inventor (s)*	*Title*	*Field of Search*
5367588	Nov. 22, 1994	K. Hill et al..	Method of fabricating Bragg grating using a silica phase grating mask and mask used by same	385/14,37,129,130, 131,147; 437/051; 430/004
5837169	Nov. 17, 1998	H. N. Rourke	Creation of Bragg reflective gratings in waveguides	264/1.24,1.27,1.31, 1.36, 285/10,37 356/400,401
5619603	April 8, 1997	R. E. Epworth, and T. Bricheno	Method of creating Bragg gratings in waveguides	385/37,123,10; 359/566, 569,573
5805751	Sept. 8, 1998	A. S. Kewitsch, et al.	Wavelength selective optical couplers	385/43,37,42,48, 46,50
5652819	July 29, 1997	R. J. Orazi	Method for tuning fiber optic coupler and multiplexers	385/51, 43, 96,37,27; 430/290

Canadian patents:

Canadian pending patent, entitled, "An Integrated Optical Board Comprising Integrated Optic Waveguide Circuit Modules". H. Hatami Hanza and V. Benham, filed on Jan 8, 1999, Canada.

Other related publications:

1. "Electron-based Technology in Microelectronics Fabrication," Edited by Goarge Barnere Published by Academic Press, 1980,
2. "Eximer Laser Photography," Kanti Jain, published in SPIE, 1989.
3. "Introduction to Microelectronics Fabrication, Molecular Series on Solid State Devices," Richard Jaeger, editors; Gerold W. Neubeck, Robert F. Pierret, Addison-Wesley Publishing Company, Vol. 5, 1993.
4. "Photosensitivity in Optical Fiber Waveguides; Application To Reflection Filter Fabrication," K.O. Hill et al.; Appl. Phys. Lett., vol. 32, No. 10, 647-649, 1978.

5. "Formation Of Bragg Gratings in Optical Fibers By A Transverse Holographic Method; G. Meltz et al, Optics Letters, vol. 14, No. 15, 823-825, 1989.

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9. "Ultraviolet light imprinted sol-gel silica glass channel waveguides on silicon," Najafi et al, published in SPIE, 38-41, vol. 2695, 1996.

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11. "Novel Writing Technique Of Long And Highly Reflective In-Fibre Gratings"; J. Martin et al; Electronics Letters 12th May 1994--vol. 30--No. 10.

12. "Very Broad Reflection Bandwidth (44nm) Chirped Fibre Gratings And Narrow Bandpass Filters Produced By The Use Of An Amplitude Mask"; M.C. Farries et al.; Electronics Letters --vol. 30--No. 11, May 26, 1994

13. "Novel Method Of Producing All Fibre Photoinduced Chirped Gratings"; R. Kashyap et al.; Electronics Letters --vol. 30--No. 12, Jun. 9, 1994

14. "Chirped Fibre Gratings Produced By Tilting The Fibre"; Y. Painchaud et al.; Electronics Letters --vol. 31--No. 3, Feb. 2, 1995

15. "Moving Fibre/Phase Mask-Scanning Beam Technique For Enhanced Flexibility in Producing Fibre Gratings With Uniform Phase Mask"; M.J. Cole et al.; Electronics Letters, vol. 31, No. 17, Aug. 17, 1995.

What is claimed is:

1. A method of writing grating on the designated areas of an optical waveguide circuit by exposure to an electromagnetic radiation comprising steps of:

A) having a planar sample with waveguides fabricated or embedded therein; the waveguides contain a photo-refractive material either in core or cladding or both, which is sensitive to a spectrum of electromagnetic radiation;

B) having a first mask with openings corresponding to the designated areas of the said sample for which we want to write gratings on the waveguides;

C) depositing a layer of masking material and transferring the pattern of the said first mask on to the surface of the said sample by lithography wherein alignment markers are also imprinted on the surface of the said sample by the said lithography process;

D) having a phase mask with identical pattern as the said first mask except phase grating are fabricated in the openings that correspond to the designated areas for writing grating on the said waveguide circuit; the said phase mask also carrying markers in the exact location as the said first mask and on the said sample;

E) placing strips of soft gaskets with a predetermined thickness on the corner edges of the sample wherein the said gaskets do not cover any part of the sample that is allocated for exposure; and placing the phase mask over the sample with the said gaskets in between at the corner edges; and pressing the said phase mask over the gaskets and then affixing the said phase mask on the said sample by clips or temporary adhesive or the like;

F) first exposure of the said sample to the said electromagnetic radiation which is passing through the said attached phase mask to create the desired refractive index changes on the designated areas of the said sample; and

G) detaching the said phase mask from the said sample and tuning the wavelength response of the waveguide circuit by locally exposing to an attenuated electromagnetic radiation to adjust the average refractive index changes or tune the optical phase in the required places using a X-Y motion table and an active monitoring of the sample response to achieve the desired wavelength response from the said waveguide circuit.

2. A method of claim 1 wherein the sample consists of one or more pieces of optical fibers embedded therein.

3. A method of claim 1 and in accordance to claim 2, wherein the said sample with fibers embedded therein is polished so that the core areas of the fibers begin to expose and then it is covered by a layer of photosensitive material such as organically modified glasses containing photo-initiators.

4. A method of claim 1 wherein the waveguide circuit covered by a photosensitive cladding layer, such as organically modified glasses containing photo-initiators, so that part of the guiding mode is propagated in this layer.

5. A method of claim 1 wherein the waveguide circuit is fabricated by sol-gel deposition method in which the core or cladding or both areas of the waveguides contain photo-refractive materials.

6. A method of claim 1 wherein the said first mask only carries the alignment markers.

7. A method of claim 1 wherein the said phase mask is fabricated by holographic projection method followed by the associated etching method.

8. A method of claim 1 wherein the said phase mask is fabricated by direct writing electron beam lithography followed by the associated etching method to fabricate the phase grating.

9. A method of claim 1 wherein the said strips of gaskets are made of soft materials with 10 to 40 percent compressibility.

10. A method of claim 1 wherein the thickness of the said gaskets is about 10 to 100 micron.

11. A method of claim 1 wherein the said gasket is a closed shape strip of a soft material that can cover the corner edges of the sample.

12. A method of claim 1 wherein the gaskets are also placed in the areas other than the corners that do not block the electromagnetic radiation on the designated areas.

13. A method of claim 1 or 12 wherein the said soft gaskets are placed over the appropriate locations over the sample by depositing a soft material with the desired

thickness over the sample and then removing the said material from the sample on the areas that might block the exposure.

14. A method of claim 1 wherein the said tuning stage is done actively by coupling a light source to the said waveguide circuit and directing a electromagnetic beam, attenuated to a desired level of intensity, with a limited beam spot size on the sample by moving the sample under the beam by means of a computer controlled X-Y motion table and monitoring the wavelength response of the circuit until achieving the desired response from the said waveguide circuit.

15. A method of claim 1 and in accordance to claim 14 wherein the wavelength response is monitored at the said first exposure with the said phase mask attached to the said sample.

16. A method of claim 1 and claim 15 and in accordance to claim 14 wherein the wavelength response is monitored at both the said first exposure and the said tuning stage.

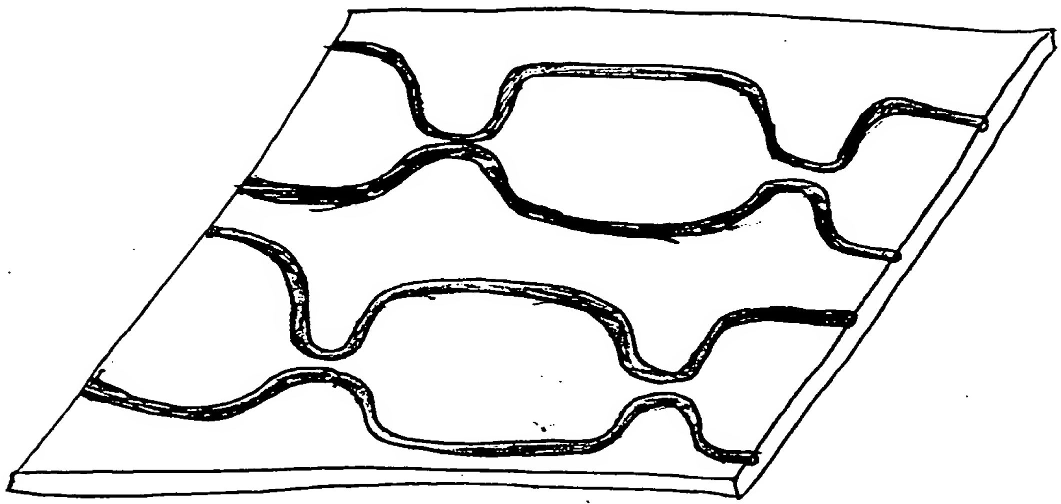

Fig. 1

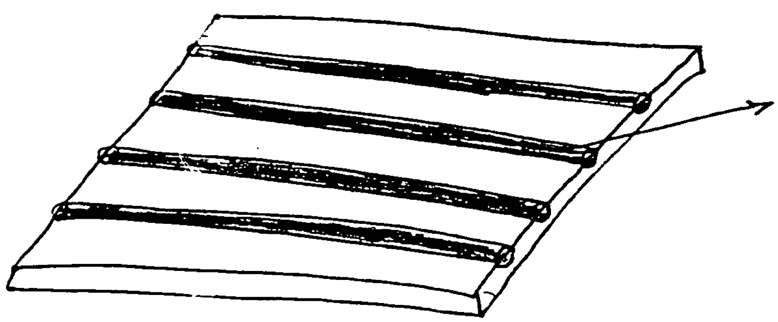

Fig. 2a

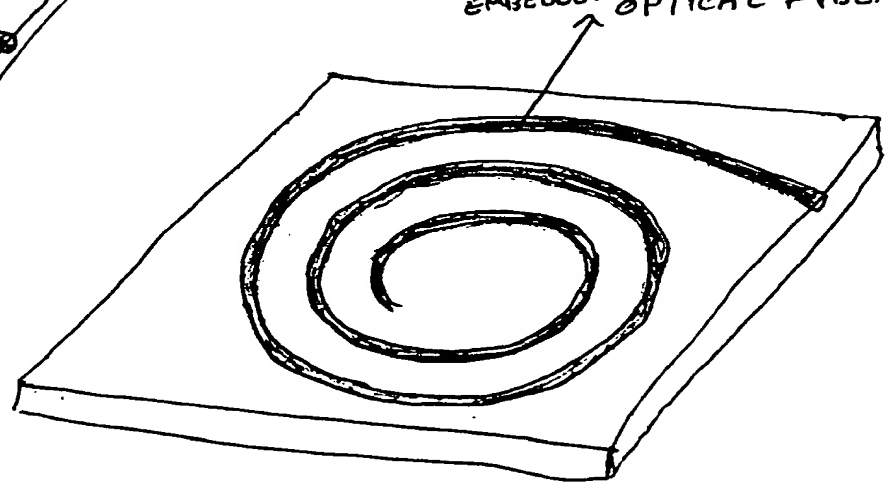

Fig 2b

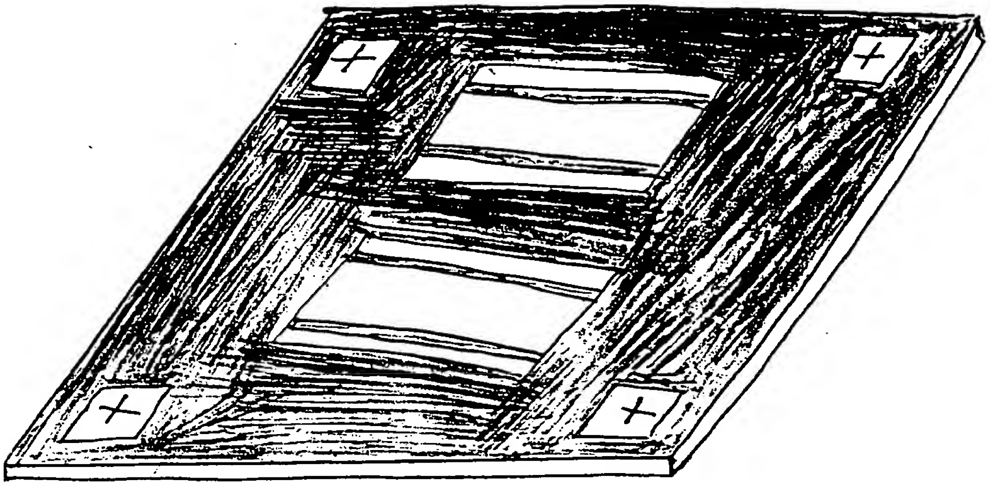

Fig 3.

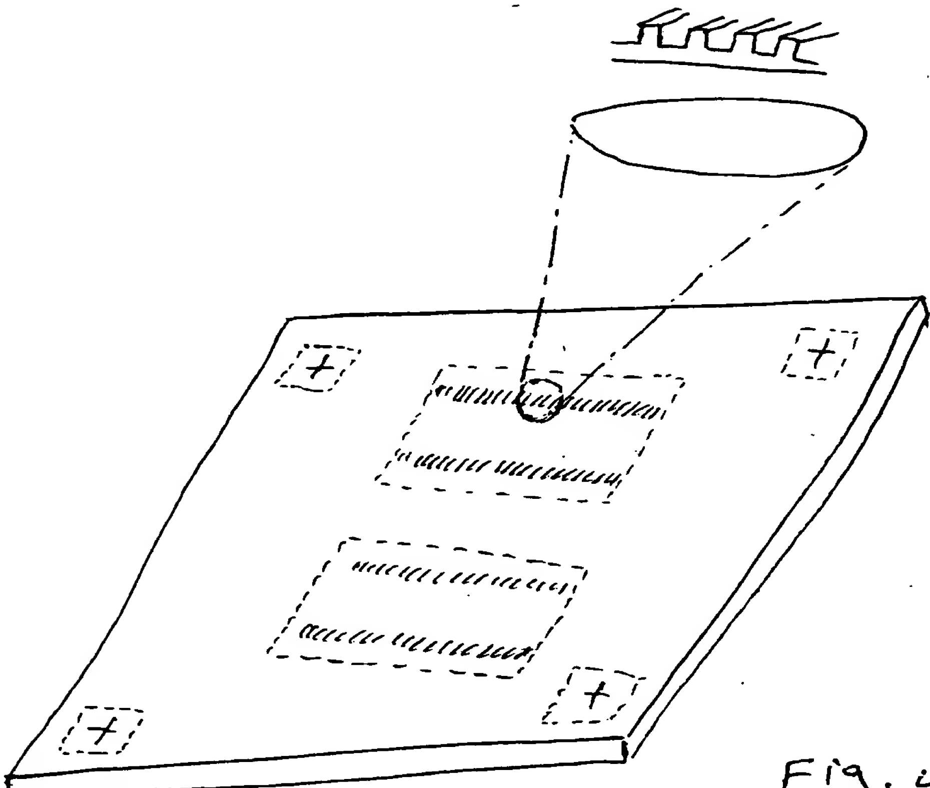

Fig. 4

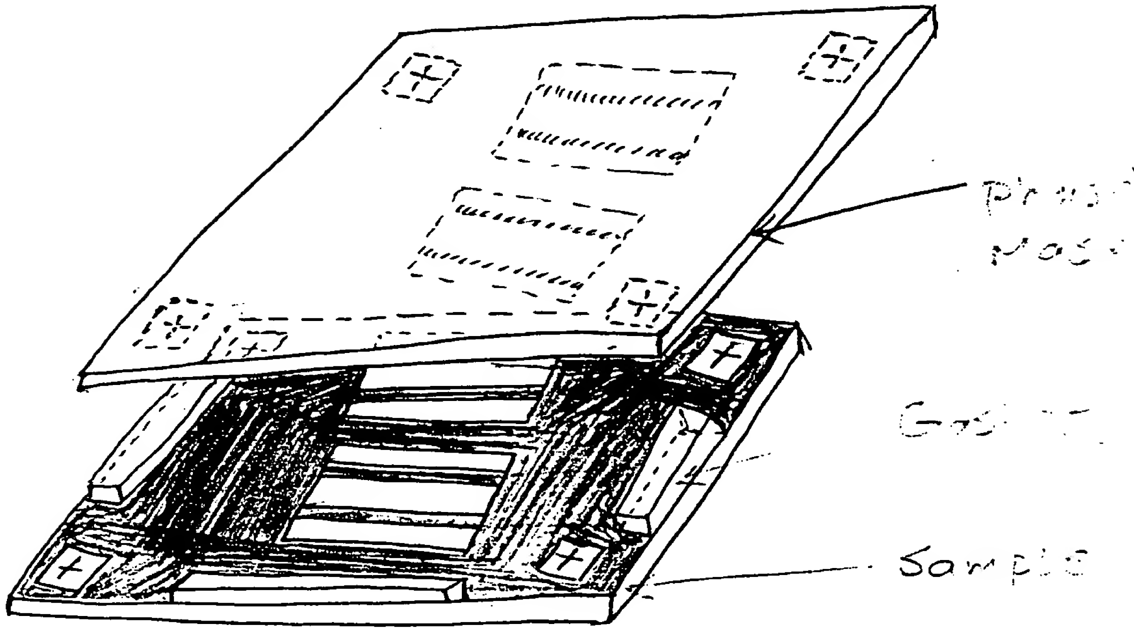

Fig. 5

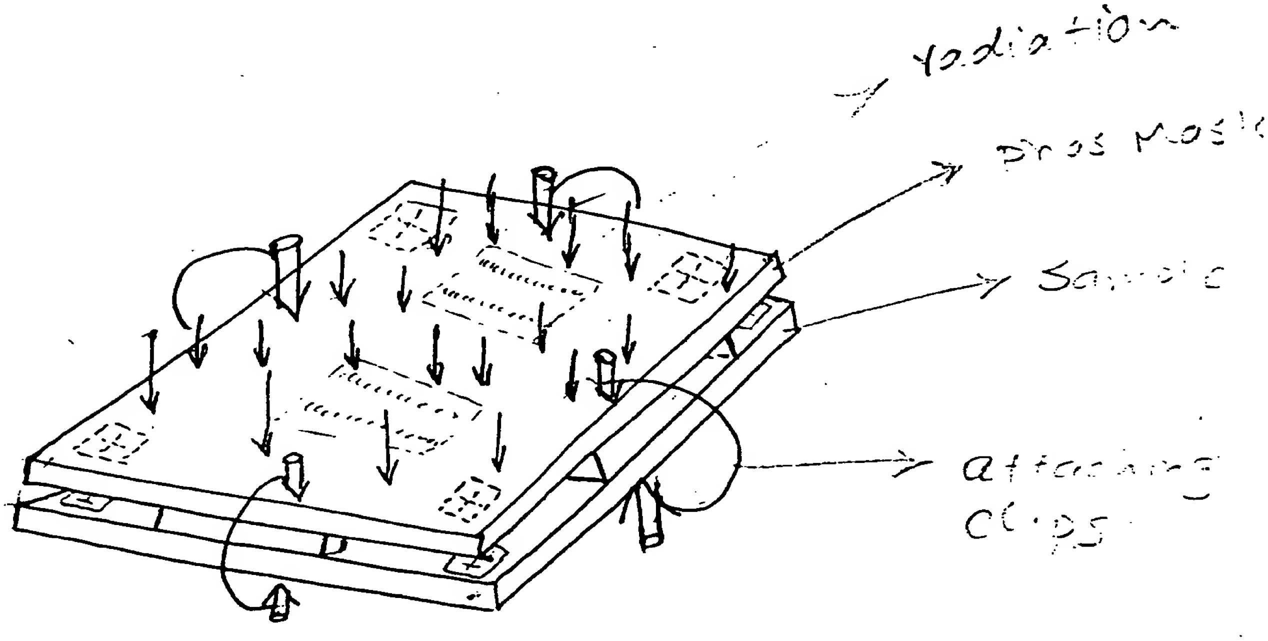

Fig. 6

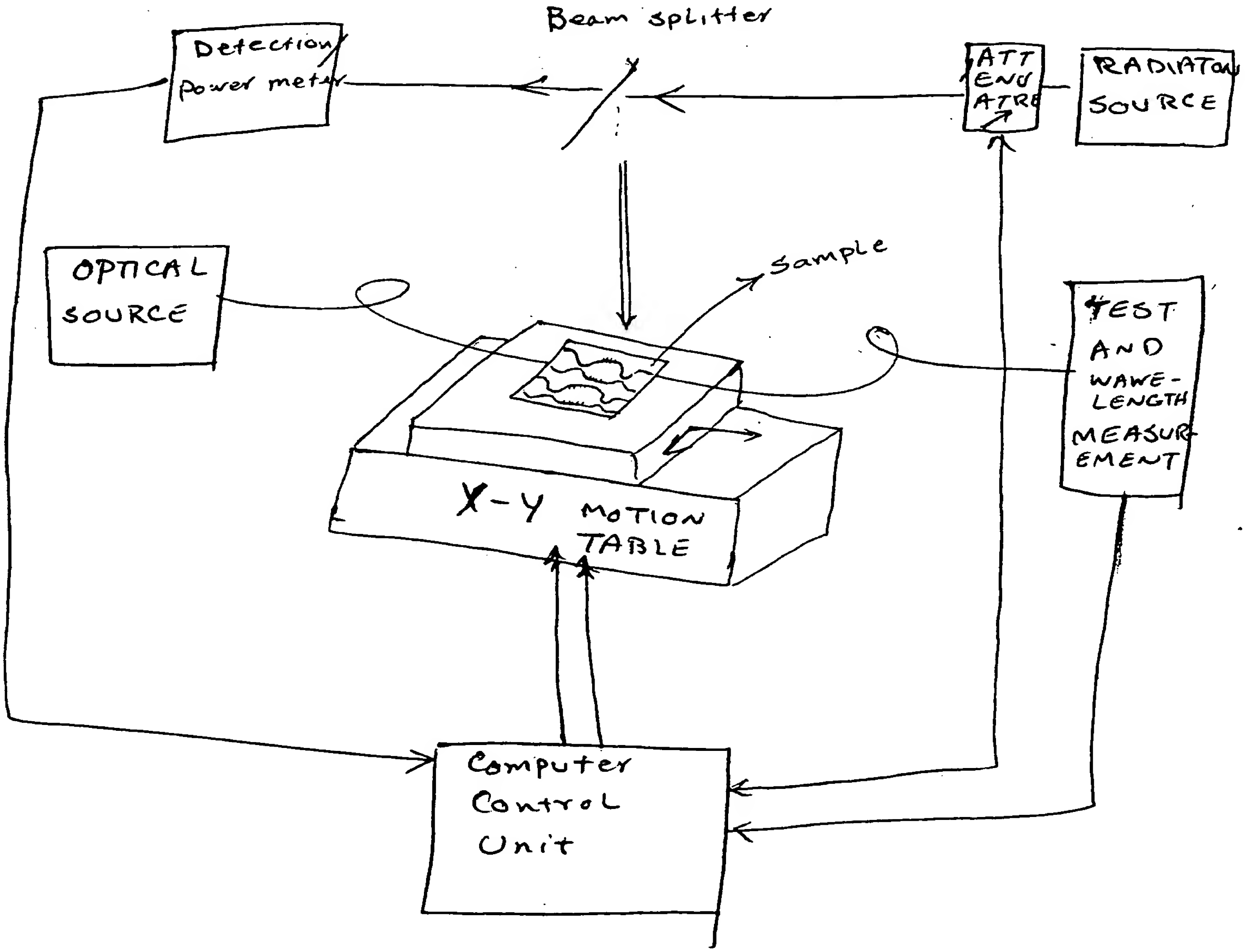
Beam splitter
Detection power meter
ATT ENU ATRE
RADIATON SOURCE
OPTICAL SOURCE
Sample
TEST AND WAWE-LENGTH MEASUREMENT
X-Y MOTION TABLE
Computer Control Unit

Fig. 7